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Attained height of lacto-ovo vegetarian children and adolescents

Joan Sabaté[1], Kristian D. Lindsted[1], Ralph D. Harris[2] and Albert Sanchez[3]

Departments of [1]Epidemiology, [2]Pediatrics, and [3]Nutrition, Loma Linda University, Schools of [1,3]Public Health and [2]Medicine, Loma Linda, CA 92350, USA

The relationship between diet and attained height was studied in children and adolescents in Southern California. Diet pattern was determined from an extensive food frequency questionnaire in 1765 Caucasian children of 7–18 years, attending state schools (452 m and 443 f) and Seventh-day Adventist schools (427 m and 443 f). The major difference in diet pattern between state and Adventist schoolchildren was in meat consumption. The Adventist children were split evenly between three categories of frequency in meat consumption (< 1/week, 1/week–< 1/d, and ≥ 1/d), while 92 percent of state school children consumed meat daily. Vegetarians (those consuming meat < 1/week) differed significantly in the consumption of other major food groups, such as fruit and vegetables. All school and diet subgroups were at or above the 50th percentile of the National Center for Health Statistics. Age-adjusted regression analysis showed that on average Adventist vegetarian children were taller than their meat-consuming classmates (2.5 and 2.0 cm for boys and girls, respectively). These results did not change materially when adjusting for other food groups. Nor did adjustment for parental height and socioeconomic factors in a sub-sample of 518 children. The results indicate that vegetarian children and adolescents on a balanced diet grow at least as tall as children who consume meat.

The growth of children consuming a vegetarian diet has been a cause for concern among health professionals for the last two decades (Committee on Nutrition, 1977; MacLean & Graham, 1980; Trahms, 1981; Vyhmeister, Register & Sommenberg, 1977; Shultz *et al.*, 1985; Jacobs & Dwyer, 1988). Several investigators have reported that some vegetarian diets may compromise or delay growth in infants and preschool-aged children (Brown & Bergan, 1975; Shull *et al.*, 1977; Dwyer *et al.*, 1978, 1979, 1980, 1983; Sanders & Purves, 1981; Fulton, Hutton & Stitt, 1980). Other studies, however, found no such effect (Trahms, Larson & Worthington, 1978; Herbert, 1985).

Limited information is available on the relationship between vegetarian diets or meat intake to attained height in older children and adolescents. Rona *et al.* (1987) found that among primary schoolchildren of various Asiatic ethnic minorities living in Britain, vegetarian girls but not boys were shorter than non-vegetarians. Recently, O'Connell *et al.* (1989) reported that the height of children up to 10 years old, raised in a vegetarian commune, was consistently below the US reference values. However, the results of these studies may be confounded by other nutritional or environmental factors. Studies with larger numbers of older children and adolescents consuming vegetarian diets and raised in a non-restrictive environment are needed to confirm this relationship.

The California Seventh-day Adventist

Correspondence to: Dr J. Sabaté

pediatric population is ideally suited to the investigation of the relationship between meat consumption and physical growth. Over 98 percent of California Adventists neither smoke nor drink alcoholic beverages (Beeson *et al.*, 1989), approximately 50 percent consume a lacto-ovo-vegetarian diet, and almost all refrain from eating pork products (Phillips *et al.*, 1978). We have found that similar dietary patterns prevail among their offspring (Sabaté *et al.*, 1990). The analytical advantage of the large variation in meat intake, from pure vegetarians to heavy meat consumers, is further enhanced by the relative homogeneity of Adventist children with respect to other environmental factors that potentially confound the diet-height relationships such as exposure to passive or active smoking. Furthermore, the availability of food choices and the adequacy of total energy intake are not limiting factors, as is often the case in vegetarian pediatric populations in developing countries.

In the present study, we report on the association between meat intake and attained height in children from Seventh-day Adventist schools who participated in the child-adolescent blood pressure study in Southern California (Harris *et al.*, 1981).

Subjects and methods

The study design and data collection procedures for the several phases of this study have been described in detail elsewhere (Harris *et al.*, 1981). In brief, during phase I, children from grades one to ten from 16 Adventist parochial schools and 13 state schools in Southern California were measured. Informed consent from the parents was obtained before data collection. Blood pressure and demographic data were documented for 7840 children or 84 percent of the eligible students. Refusal rates were low, less than 2 percent. The major limiting factor in obtaining data was absence from school on days the field team collected data (14 percent).

Phase II data collection was carried out a year later and limited to Caucasian children. Dietary information, height, and weight, along with further blood pressure measurements were taken at the school premises from 870 Adventist and 895 state schoolchildren aged 7–18 years, who had been randomly sampled from the upper, intermediate and lower levels of the phase I blood pressure distributions for each age, sex and school group. The participation rate was 78 percent and, as in phase I, absence from the school on the days the field team collected data was the primary reason for non-participation.

In phase III of the study, parents were visited at their homes. Study field workers measured height of the head of household and spouse and collected information from each one on demographic characteristics. Due to the high cost of home visitation, parents' participation was limited to two-thirds of phase II children. Sampling was based on blood pressure distribution of the children. Response rates for mothers and fathers were 89 percent and 84 percent, respectively.

To characterize the dietary habits of this young study population, a non-quantitative food frequency questionnaire was developed (Williams, 1978) and pretested (Corder, Phillips & Kissinger, unpublished data, 1978) on 211 students, age 9 years and older. In this pilot study, frequency of consumption of six principal food groups was compared to information derived from a 24-h recall. In the principal food groups the Spearman's coefficient of correlation between the two types of diet collection methodology was 0.77; however, for the 'junk foods' group this decreased to 0.41.

The final questionnaire had 106 items and was self-administered by all children age 10 or older, and completed by the mothers for children younger than 10 years. Frequency choices were: never (almost never), every month (sometimes), every week (often), and every day (very often). For each child we constructed a simple frequency index giving approximate monthly consumption of foods, for each of six food groups: 1) meat, including poultry and fish; 2) eggs and dairy products, including milk, cheese, ice cream, and yoghurt; 3) fruit and vegetables, both fresh and canned; 4) starchy foods, viz. bread, cereals, pasta, and legumes; 5) 'junk foods', viz. candy, cookies, potato chips and other snack foods; and 6) vegetable protein

products comprising meat substitutes. The indexes were calculated as the sum of the reported food frequencies for each food in the group.

A child consuming meat less than once per week was defined as a vegetarian. This definition has been used previously in other studies relating dietary habits of Adventists to health/disease outcomes (Snowdon, Phillips & Fraser, 1984). A child was defined as a low meat-consumer if his/her intake of meat products was one or more times per week, but less than once per day, and a medium/high meat-consumer if meat was consumed one or more times per day.

Height was recorded to the nearest ¼ inch, using a portable stadiometer, with the subject standing erect without shoes and without upward pressure exerted on the mastoids. Two observers recorded height measurements. Age was computed by subtracting the birth date from the anthropometric data collection date. Age was used as a continuous variable for all analyses.

To test for significant differences in attained height among the dietary subgroups, we performed sex-specific, age-adjusted multiple linear regression analyses, using the SPSS program (Norusis, 1986). Since height may not be linearly related to age, we first fitted the best model between height and age for each sex. Selection criteria for the best model was the highest proportion of variation explained (R^2) with minimal collinearity. Age and age cubed were included in all models as independent variables. The inclusion of other exponents of age did not improve the model. The estimated effect of vegetarian diet was obtained as the regression coefficient for the binary variable indicating vegetarian status.

To control for social and biological factors known to influence the height of children, fathers' and mothers' height and selected demographic variables were used in regression models for second stage analysis of the children who reached phase III of the study. Parents' height and mothers' education (number of years of formal schooling) were included as continuous variables, while fathers' present occupation (blue/white collar profession) and total family income (below/above $15 000/year) were used as binary variables.

Results

The meat consumption of Adventist schoolchildren was strikingly different from that of state schoolchildren (Table 1). Approximately one-third of the Adventist children were vegetarians, another third were low meat consumers, and the rest were in the medium/high category. In contrast, 92 percent of state school students were in the medium/high group, 7.6 percent were low meat consumers and only one child was a vegetarian. Sex-specific meat consumption habits for Adventist children is also shown in Table 1. Table 2 compares the food

Table 1. Distribution of State and Adventist schoolchildren according to frequency of meat consumption.

	Vegetarians (<1/week)	*Low meat intake (1/week – <1/d)*	*Medium/high meat intake (1 or more/d)*
State schoolchildren (n = 895)	0.1% (1)	7.6% (68)	92.3% (826)
Adventist children (n = 870)	32.5% (283)	36.3% (316)	31.1% (271)
Adventist boys (n = 427)	28.8% (123)	34.0% (145)	37.2% (159)
Adventist girls (n = 443)	36.1% (160)	38.6% (171)	25.3% (112)

Table 2. Frequency of use (times per month; mean ± s.d.) of six food groups by Adventist schoolchildren according to vegetarian status.

Food groups	*Frequency of food use* *Vegetarians (n = 283)*	*Meat consumers (n = 587)*	*P**
Meats	0.6 ± 1.3 (0–0)[a]	40.9 ± 42.5 (14–52)	<0.001
Eggs and dairy products	75.8 ± 31.0 (56–90)	88.9 ± 39.5 (62–108)	<0.001
Fruit and vegetables	140.5 ± 64.6 (90–186)	111.6 ± 60.3 (65–144)	<0.001
Starchy foods	90.3 ± 37.8 (64–106)	81.3 ± 40.2 (54–98)	0.002
Junk foods	51.7 ± 37.1 (27–62)	74.4 ± 48.4 (41–94)	<0.001
Vegetable protein products	43.6 ± 33.1 (20–56)	27.7 ± 32.0 (6–35)	<0.001

* *P* value by *t*-test comparing the mean frequency of use between the diet groups.
[a] Values in brackets are the interquartile range of 25th–75th percentiles.

consumption patterns for the other five food groups according to vegetarian status for the Adventist schoolchildren. There were significant differences for all the food groups.

Tables 3 and 4 show the age- and sex-specific mean heights for both vegetarian and meat-consuming Adventist schoolchildren. For comparison, the mean heights of state schoolchildren were added. For all school and diet groups, mean heights were at or above the 50th percentile of the National Center for Health Statistics reference values (Hamill *et al.*, 1979). For most age categories, mean heights of vegetarian boys and girls were similar to or greater than those of meat consumers from either Adventist or state schools.

Table 5 presents the results of age-adjusted regression analysis comparing vegetarians to meat consumers among the Adventist children. Vegetarian boys and girls were, respectively, 2.5 cm and 2.0 cm taller than the meat consumers. Further analysis with meat consumers subdivided into two cate-

Table 3. Mean heights for boys by age, school type and vegetarian status.

Age[a] (years)	*Seventh-day Adventist schools* *Vegetarians (n = 123)*			*Meat consumers (n = 304)*			*State schools (n = 452)*		
	n	*Mean (cm)*	*s.d.*	*n*	*Mean (cm)*	*s.d.*	*n*	*Mean (cm)*	*s.d.*
7							3	120.9	8.3
8	7	130.6	4.9	6	129.0	4.5	20	128.6	5.3
9	6	135.9	5.4	14	136.3	6.2	18	136.1	6.2
10	16	139.6	6.7	12	141.2	5.5	27	139.7	6.3
11	15	144.8	3.8	33	144.4	6.3	35	145.1	7.3
12	11	152.3	7.0	43	150.9	6.3	49	148.6	7.9
13	15	160.2	6.0	55	158.0	8.0	36	157.3	8.5
14	13	165.0	6.3	53	165.8	9.2	67	163.7	8.6
15	21	177.6	7.5	41	171.4	8.0	54	169.6	9.8
16	16	177.9	8.1	26	176.4	9.2	82	175.2	8.0
17	3	181.8	2.7	17	177.5	6.1	55	176.7	6.9
18				4	177.8	3.8	6	182.9	6.3

[a] The 7-year category includes children aged 6.5–7.49 years, the 8-year category those aged 7.5–8.49, etc.

Table 4. Mean heights for girls by age, school type and vegetarian status.

Age[a] (years)	Seventh-day Adventist schools: Vegetarians (n = 160) n	Mean (cm)	s.d.	Meat consumers (n = 283) n	Mean (cm)	s.d.	State schools (n = 443) n	Mean (cm)	s.d.
7	2	128.3	1.8				5	119.5	4.8
8	8	133.9	6.0	15	128.6	7.1	19	126.0	7.3
9	14	133.1	4.8	13	131.9	6.2	16	134.4	3.3
10	16	142.7	6.3	16	138.7	5.5	15	140.0	6.0
11	14	146.7	6.1	32	146.1	6.4	58	148.3	7.4
12	17	151.2	7.5	24	150.3	7.6	48	152.0	8.2
13	18	159.5	4.8	34	158.2	6.5	33	158.8	8.1
14	21	166.2	5.7	60	162.5	6.2	67	162.3	5.7
15	28	166.3	6.1	50	162.7	5.3	57	164.6	7.2
16	15	163.7	6.0	27	164.2	5.8	85	164.8	6.4
17	6	165.8	6.5	10	161.6	6.0	38	163.4	5.1
18	1	164.5	—	2	166.4	6.3	2	168.3	2.7

[a] See footnote to table 3.

Table 5. Estimated effect of vegetarian diet on attained height in Seventh-day Adventist schoolchildren.

Term	Boys (n = 427) Regression coefficient	(s.e.)	P	Girls (n = 443) Regression coefficient	(s.e.)	P
Vegetarian status*	2.46 cm	(0.086)	0.002	2.03 cm	(0.616)	0.001
Age (years)	7.29 cm	(0.790)	<0.001	10.80 cm	(0.607)	<0.001
Age cubed (years^3)	−0.0025 cm	(−0.0015)	0.104	−0.013 cm	(−0.0012)	<0.001
Constant	69.07 cm	(6.74)	<0.001	45.62 cm	(5.01)	<0.001

* Vegetarian status defined as meat consumption of <1/week, compared to meat consumers.

gories, low or medium/high as previously defined, did not substantially alter these results.

Since it is possible that the effect of meat intake was confounded by other foods, we performed multiple regression analyses adjusting simultaneously for age and the other five food groups previously described (Table 2). The estimated effect for vegetarian boys and girls was, respectively 1.9 cm (P = 0.03) and 2.1 cm (P = 0.002) when compared to their meat-eating counterparts, confirming the difference in attained height between vegetarians and meat consumers.

Table 6 presents regression analyses results on a sub-sample of 241 boys and 277 girls for which the heights of their biological mothers and/or fathers were measured (during phase III of the study). Vegetarian boys and girls were, respectively, 1.8 cm (P = 0.06) and 1.9 cm (P = 0.01) taller than their meat-consuming classmates after controlling for age and parents' height, and fathers' occupation. Further analysis with other socioeconomic factors in the model, such as family income and mothers' education, gave very similar results.

Discussion

A previous report from this cohort demonstrated that a health-oriented lifestyle during late childhood and adolescence, such as the one followed by many Adventists, sustains adequate physical growth (Sabaté *et al.*, 1990). The present results extend our earlier

Table 6. Estimated effect for various predictors of attained height in a sub-sample of Seventh-day Adventist schoolchildren.

	Boys (n = 241)			*Girls (n = 277)*		
Term	*Regression coefficient*	*(s.e.)*	*P*	*Regression coefficient*	*(s.e.)*	*P*
Vegetarian status*	1.85 cm	(0.973)	0.059	1.86 cm	(0.736)	0.012
Mother's height (cm)	0.32 cm	(0.077)	<0.001	0.32 cm	(0.062)	<0.001
Father's height (cm)	0.32 cm	(0.094)	<0.001	0.29 cm	(0.063)	<0.001
Father's occupation**	0.07 cm	(0.970)	0.940	−0.28 cm	(0.778)	<0.723

Age and age cubed are also included in the model.
* Vegetarian status defined as meat consumption of <1 week, compared to meat consumers.
** Blue versus white collar professions.

findings by showing that in Adventist children and adolescents the vegetarian diet is associated with taller stature. Apparently, meat intake (or other factors closely associated with it) is negatively associated with height in this age range, with a possible threshold effect at very low intake. This may indicate that the apparent negative effect of meat observed in this study can only be detected at low levels of meat consumption, but further increases have no additional effect.

Alternative dietary explanations as to why the vegetarians were taller must be considered. Vegetarian children consume less junk foods and dairy products but more starchy foods, vegetable protein products, and fruit and vegetables than do those who consume meat (Table 2). One or more of these foods, or the differences in eating patterns between the groups, may be related to growth. It is worth noting that the lacto-ovo vegetarian children in this study, on the average, had a much lower total animal protein intake (Table 2). The absence of meat in their diets did not increase their consumption of eggs and dairy products. Vegetable protein products have been shown to be adequate substitutes for meat in animal growth studies (Sanchez, Porter & Register, 1966) and in nitrogen balance studies in humans (Register *et al.*, 1967); however, the effect of long-term use of these foods on children's growth has not been studied. Regression analysis with simultaneous adjustment for all food groups did not substantially alter these results, but these indices may not completely adjust for other dietary differences.

Variations in genetic potential could exist between the vegetarian and non-vegetarian children. Parental heights are proxy measures of the genetic influence on height. Unfortunately, we do not have these variables for the entire study population, although analysis with available data on a sub-sample of children argues against this explanation.

Further control for socioeconomic variables known to relate to the attained height of school-aged children in other populations (Tanner, 1962; Rona, Swan & Altman, 1978) did not change the results. Moreover, differential exposure to passive smoking and other adverse factors pertaining to lifestyle are very unlikely to have confounded the dietary effects on height in our population, since there is virtual absence of cigarette smoking in this population (Beeson *et al.*, 1989; Phillips *et al.*, 1978; Wynder & Lemon, 1958). For older children, the reported difference in height related to passive smoking was only a few millimeters (Berkey *et al.*, 1984; Rautakallio, 1984; Rona *et al.*, 1981).

The results of this study do not prove that

vegetarian children will be taller in adult age since differences in maturation may exist among the dietary groups. Sexual and other maturation parameters were not assessed in the present study, making it impossible to determine whether the height differences observed between the dietary groups were related to maturation. However, in a previous report we found no differences in timing of growth spurts in Adventist boys and a delayed onset in girls when compared to state schoolchildren (Sabaté *et al.*, 1990). We have also noted a later age of menarche in vegetarian girls compared to meat-consumers from the same geographical area (Kissinger & Sanchez, 1987; Sanchez, Kissinger & Phillips, 1981).

The cross-sectional design of this study shares limitations with most of the published literature on vegetarian diets and growth, namely the inability to assess temporality of the events and self-selection into the diet groups. However, it does seem improbable in our population that height would determine diet selection.

Regardless of its limitations, this is one of the few epidemiological studies to find a relationship between food intake and growth in a developed country (Rona, 1984). By contrast, most other studies report the absence of such a relationship (Hackett *et al.*, 1984; Vermeersch, Hanes & Gale, 1984; Rona & Chinn, 1989). The participants' wide range of meat intake and the large number of subjects at both extremes of the spectrum (vegetarians versus heavy meat consumers) may have contributed to these results. Adventist children provide a unique opportunity to study the possible effect of a vegetarian diet on physical growth because of their large variation in meat consumption and the relative homogeneity with respect to other environmental factors that frequently confound the diet-height relationship, such as passive smoking.

In conclusion, the results of this study support the view that meat intake is not essential for normal growth of older children and adolescents. A lacto-ovo-vegetarian diet is compatible with and conducive to normal physical growth in this age range. Growth retardation often observed in vegetarian children from developing countries apparently is caused by factors other than low meat intake.

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